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CFD Analysis of Transonic Cavity Flow Using DES and LES

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Background

- Problems occur when weapon bay doors are opened to release store
- Exposure to free-stream produces undesirable effects
  - Depends on weapon bay geometry (modelled using a cavity)

- Reduced aircraft drag
- Enhanced manoeuvrability
- Reduced aerodynamic heating of stores
- Reduced radar cross-section
Background

- Open cavities:
  - Shear layer spans cavity
  - Acoustic pressure waves propagate externally and internally
  - Mass ejection/injection
  - High noise levels & frequencies

- Closed cavities:
  - Separation, re-attachment, separation
  - Large pitching moments
  - Store separation & release problems

- 3D, L/D = 5, W/D = 1, M=0.85
  - open cavity
Experimental Data: Pressure

- Source: DERA (Bedford, UK) – Ross, Wrisdale, Peto (2000)
- Geometry: Empty cavity, L/D = 5, W/D = 1, doors-off & doors-on
- Pressure transducers (doors-off & doors-on), PIV (doors-on)
- Flow Conditions: $M = 0.85$, $Re_L = 6.783 \times 10^6$
3D Computational Domain

$L/D = 5$, $W/D = 1$
Doors-On Results: Cavity Floor

SPLs

PSD (x/L = 0.95)
Doors-On Results: Cavity Floor

Band-Limited SPLs

50 Hz ≤ f ≤ 250 Hz

350 Hz ≤ f ≤ 450 Hz
Doors-On Results: Cavity Floor

Band-Limited SPLs

500 Hz ≤ f ≤ 700 Hz

750 Hz ≤ f ≤ 850 Hz
Doors-Off Results: Cavity Floor

SPLs

PSD (x/L=0.95)
Doors-Off Results: Cavity Floor

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Doors-Off Results: Flow-Field

Instantaneous Mach Contours
Doors-Off Results: Flow-Field

Instantaneous Mach Contours
Doors-Off Results: Flow-Field

Baseline $k-\omega$

Instantaneous Mach Contours

DES-SA

LES

TimeStep = 9000
LD=5, DES-SA, Doors-Off (2.2 m) - Mach Contours

TimeStep = 45000
LD=5, LES, Doors-Off (4.7 m) - Mach Contours
PIV Comparisons: Doors-On

Streamwise (U) Velocity Profiles

- $x/L = 0.05$
- $x/L = 0.55$
- $x/L = 0.95$
PIV Comparisons: PIV Resolution

Streamwise (U) Velocity

Transverse (V) Velocity
Conclusions – Clean Cavity

• Doors-On:
  – 2nd Rossiter mode (380 Hz) dominant
  – URANS compares well with experiment SPLs but closer inspection reveals poor comparison at high frequencies
  – DES/LES fares much better: captures higher frequencies & amplitudes

• Doors-Off:
  – 3rd Rossiter Mode (600Hz) dominant
  – URANS still predicts characteristics of 'doors-on' results
  – LES/DES consistently predict correct SPLs & flow features
  – URANS results poor due to failure in predicting shear layer break down

• Good comparison between LES/DES and PIV
Further Work

• Parametric studies:
  – L/W, Re, M effects

• Cavity with stores:
  – Missile with(out) fins
  – Missile in different cavity locations
  – Missile inside different cavity geometries/configurations

• Flow Control:
  – Pulsating jet
  – Closed loop control strategies (cost-effective but difficult to implement)

• Possible flow control strategies with missile in cavity
• Flow acoustics
Questions?